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Cloud Computing: Analysis of Cloud Storage In Robotic Environment

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***Abstract*— Cloud is a well-designed data storage model concerned with the storage of information on web. This model has greatly revolutionized the robotic environment for learning purpose. This paper will provide you an overview of how a database in cloud is capable of storing knowledge resulted from the combined effort of human as well as robot in robot understandable open format that will support existing as well as forthcoming robots learn faster. As such the robots will pick up the aggregate knowledge from its environment and accumulate the same in the cloud storage from where they get the support to perform a set of tasks including navigation, task information like how to pick up an object, and object-recognition of data in order to construct a map of the environment without having any knowledge in advance, and to simultaneously confine itself in the unknown environment through the process of learning.**

Keywords—cloud, storage, knowledge, robotics, robobrain, rapyuta

I. INTRODUCTION

From the decades, it has been noticed that robots are mainly empowered with programming embedded in a chip but a small defect could result into malfunctioning of the whole unit and hence affect learning ability of robots. As such certain mechanism is required that will provide guarantee in terms of reliability, security and robustness. Due to great processing power of cloud it paved the way as an appropriate utility in Robotic Environment. Cloud robotics is one such step taken towards, that has evolved idea of leveraging the Internet for robots, and offers extraordinary opportunities for robot learning. Instead of using the World Wide Web for rapid communication or faster reckoning, a key factor is allow robots to generate and collaboratively update shared knowledge repositories. Such knowledge bases will power robots to deal with the intricacies of human environments and offer a simple yet powerful way for life-long robot learning. [1] The goal of the European-Commission-funded initiative is to develop proof-of-concept demonstrations that show how cloud repositories like RoboEarth's databases can greatly speed up robot learning and how they may ultimately allow robots to perform well beyond their preprogrammed behaviors. As such many AI Researchers are putting effort in establishing a database in cloud which they called it "RoboBrain" that will house all the information robots have learned up till now and help them further their knowledge by sharing that knowledge.

On the developer's hand, they will have access to RoboBrain's massive database, free of charge and wirelessly. [2] Aditya Jami, from Cornell, who designed the database for RoboBrain said this about it: "The RoboBrain will look like a gigantic, branching graph with abilities for multi-dimensional queries." By sharing parameters, data, files and everything else robots have gathered till now, their developers will access and automatize the process of robot's understanding of their locality and ambiances, including speech and voice recognition, grasping, navigating and perception of different objects. Year, 2010 firstly marked the self-driving cars came in our lives which afterwards tracked by RoboEarth (a kind of system which allow robots to exchange knowledge among them).

II. LITERATURE REVIEW

A. Cloud Robotics

Cloud Robotics is a specialized application of cloud computing that deals with the study of robots and their environment. Due to cloud all the data will get stored on the web which has greatly boosted the robots ability to perform all their working by sharing experience with each other in order to provide a precise response. Due to connection with cloud network it is easier for robots to collaborate with other objects, machines and human beings. At the same time, internet has highly augmented the capabilities of robots by providing service on demand and offload computation. Cloud robotics has greatly overcome the problem of network robotics due to their resource, information and communication constraints. With the arrival of cloud robotics expenditure of maintenance and updates and requirement of custom middleware has solved up to a great extent.

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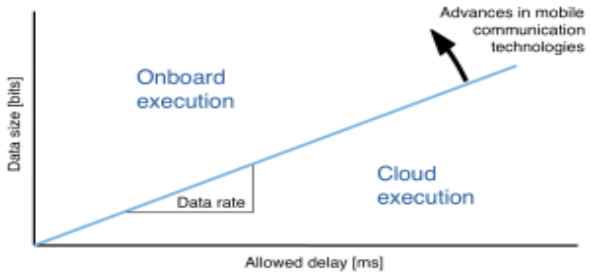

Fig 1: *Advances in mobile communication technologies, resulting into more robotics applications execution in the cloud* [3].

Robots are able to perform some computationally heavy tasks such as mapping, planning and probabilistic interference through the accessibility of huge computational infrastructure. RoboEarth is one such attempt that offers a cloud based infrastructure, and can help a robot to send some data to cloud and get the data back from the cloud in some other form. RoboEarth is a kind of database that stores the knowledge generated by either humans or robots but in a machine readable format. RoboEarth knowledge base is supposed to consist of a variety of data including task knowledge (e.g. manipulation strategies, action recipes etc.), several software components, maps for navigation (e.g. world models and location of objects), model that aids in recognition of different objects.(e.g. object models, images). Rapyuta which is also considered as the RoboEarth cloud engine is highly responsible for powerful computations to the robots. It is implemented as Platform-as-aService which is open source designed to suit robotics application. It enables the robots to unburden heavy computation to protect cloud's computing environment with marginal configuration. Rapyuta is considered to provide efficient access to the bandwidth which in turn provide access to the repository of knowledge on cloud and thus enabling robots to learn skills and share experience with other robots. The components of the cloud robotics are so well structured and interconnected that they provide the environment for the deployment of large robotic teams.

B. Software Components

RoboEarth system is powered with the cloud infrastructure which in turn supported by RoboEarth databases and RoboEarth cloud engine (Rapyuta) in addition with several software components. Such software components are responsible to interact with the RoboEarth database in order to request and store data and can be set up for their execution in cloud engine or locally on the robot. In certain scenario these components can also be used independently.

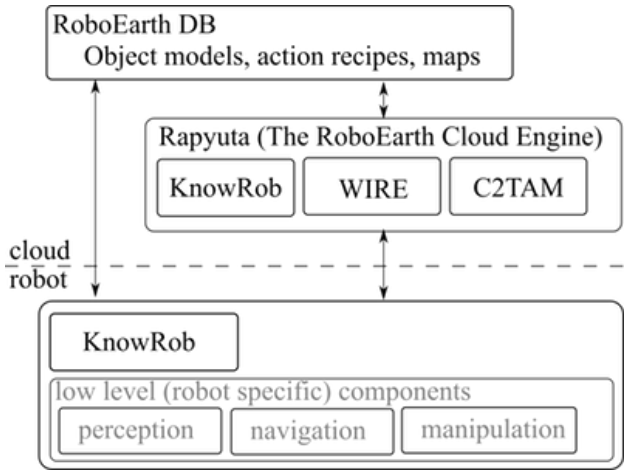

Fig 2: Architectural diagram of the integrated RoboEarth system [4].

Rapyuta: Rapyuta is a framework which is an open source framework having utility in cloud robotics. Figure 3 as given below provides a streamlined overview of the Rapyuta framework: Each robot attached to the Rapyuta is having a secured computing environment (rectangular boxes) enhancing their capability to transfer their heavy calculation into the cloud. Computing environment are interconnected in a wellstructured way and have a high bandwidth connectivity to the repository of knowledge as shown in the figure by stacked circular disks.

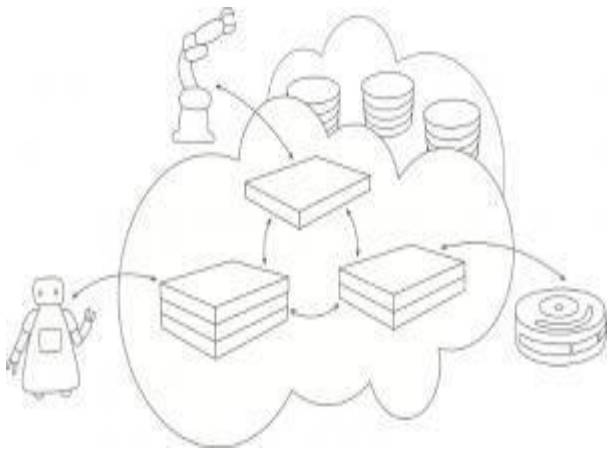

Fig 3: Rapyuta: A Cloud Robotics Framework [5]

RoboEarth DB: The Apache Hadoop based WWW- style database used to store essential data for the robots.

KnowRob: It is a system involved in the processing of knowledge that groups reasoning methods and knowledge representation with several techniques for acquiring and embedding the knowledge in a physical system. It also serves as a framework that gathers knowledge from the various sources and is utilized in RoboEarth as a local knowledge base for robots.

Object Adapter: These are the set of ROS packages that enables both robots and users to form a cloud model (point cloud

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model) from an object making use of marker pattern, so that the resulting model can be stored in the RoboEarth's repository of knowledge, and allow to download the object models later and used them for detecting objects.

WIRE: The WIRE stack allows to produce and retain one consistent world state estimate grounded on object detections. It is highly involved in the data association problem by maintaining multiple postulates and assists tracing of various object attributes.

C2TAM: C2TAM implements a system called visual SLAM which is dependent upon a distributed framework where the storage and expensive map optimization is allocated on an external server, whereas a light camera tracking client executes on the local machine. The robot onboard computers are released from a burden of computation, with only internet connection being an extra requirement.

III. APPLICATION OF CLOUD STORAGE IN ROBOTICS

Cloud Based Robotics has proved to have a number of applications and advantages over the traditional networked based robotics.

- Cloud storage provides a shared knowledge database by which the robots can easily share their information with each other and can aligned themselves to work collaboratively in order to achieve a common task.
- Cloud robotics offloads the computing tasks to the cloud which involves heavy computation. Moreover cloud robotics is cheaper, easier to maintain hardware and lighter which results in the long battery life. CPU hardware upgrades are undetectable and hassle free.
- Data mining is the history of all cloud enabled robots. Cloud Robotics involves skilled and well maintained database. Reusable library of skills or behaviors maps to perceived tasks requirements/complex situations.
- Due to these advantages, cloud robotics had a wide range of potential applications in the computationintensive or data-intensive tasks in the areas of health care, intelligent transportation, environment monitoring, smart home, entertainment, education and defense. In this section, we discuss the opportunity and challenges that cloud robotics brings to traditional robotic applications. Specifically we focus upon three robotic applications: Robotic Surgery, Defense and navigation.

A. Robotic Surgery

Consider a scenario where a situation demands instant operation of a patient but the problem is doctor is not available. Then to tackle with that situation Robots can help because they can capture the useful knowledge from the cloud regarding the operation tips as mentioned by the other robot who previously have tackled with the same situation who is currently present somewhere else. In this way the whole operation can be executed in a safe and reliable manner.

B. Defense

Cloud robotics has a huge application in defense where they can sense the area which has the maximum probability of finding enemy by selecting the appropriate map from cloud storage at appropriate time. Cloud storage can be fed with updated maps from time to time with the help of satellites. As such human life can be saved by using robots in place of them at the time of world war or any war happening in the country.

C. Navigation

Robotic Navigation involves a robot identifying its own position with respect to a certain reference by choosing an appropriate path from there to reach the desired destination from all possible paths available. Such activity involves a collection of tasks such as localization, path planning and mapping. Two types of approaches are available: mapless and map based approach [13]. Mapless approaches is based on the observation and perception of the sensors used in navigation. Due to the limited onboard resources, these approaches usually suffers from reliability issues. Map based robotic navigation is comparatively better then mapless if the map is available. It can either use an unknown map or build a map during navigation. On the other hand building maps requires too much computation and storage requirements. However, if the area is large process of creating map requires access to vast amount of data which is a challenging task. Cloud robotics highly aids cloud based navigation by facilitating the following two properties: In addition to provide vast storage space to store the large amount of map data, cloud also provide processing power to facilitate the construction and searching of the map quickly. Secondly, commercially available maps (e.g. Google maps, bing maps) can also be leveraged to develop consistent, active, and high range independent navigation solutions.

IV. SHORTCOMINGS OF CLOUD STORAGE IN ROBOTICS

One of the key issue regarding cloud robotics is threat to cloud storage which is highly vulnerable to malicious attacks. Moreover the wireless network over which the robot communicate with cloud in order to exchange information can be challenged at any instant of time. As such certain security mechanism need to be provided that will result in the increased overhead of the overall system. As discussed, previously that a developer has an access over the cloud. In the same manner if an intruder get access to the cloud somehow then it might be possible the same intruder will replace the existing information in cloud with some other malicious information that will result in the malfunctioning of robots which may prove to be highly destructive.

Several other limitations of cloud robotics:-

1. As discussed in section II cloud supports the software part of the robot and it doesn't have to deal with the hardware structure of the robots. So, it offload the hassle and costs of IT management.

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2. Cloud robotics relies heavily on the cloud which in turn depends upon internet connection. So, if internet service will get affected from frequent outages or slow speed it fails to help the robots to continue their frequent communication in order to share knowledge from knowledge repository present on the cloud.

3. It is a hard fact to digest that robotics is lacking emotion. Such thing imparts a huge impact on the people because of their adjustment with the machinery robots because there is high probability of thinking mismatch between them. Consider a havoc where the people are suffering from the local environment conditions. As such if certain robotic team is send there for the rescue operation for their safety it is very hard for the humans to believe upon them.

V. Possible Solutions And Future Scope

- Instead of fetching knowledge every time to perform an operation from cloud. A robot must be able to remember the already done tasks in order to tackle the same situation next time but at faster rate with greater efficiency.

- Robots can be taught to handle many different tasks through the installation of robotic apps. Very soon, these robots will be upgradable real-time by connecting to the cloud and downloading apps from there [9].
- An app store for robots – Downloading apps from the app store is one the biggest reality behind smartphones success. In the same way Robot Apps can be used to control the robot and imparting intelligence in them. Some Apps allow you to generate predefined-programmed movement sequences, while others are used for remote control, whereas software development platforms are used to make more sophisticated autonomous control systems.

VI. Conclusion

We have discussed a scenario where future robotics will rely heavily on cloud storage that will enhance their capability and functionality in terms of learning and sharing information in order to work collaboratively to achieve some goal which was limited earlier due to limited programming. Cloud storage also enabled the developers due to their accessibility to the cloud to control and coordinate the robot activities at any point where the situation demands that may not be favorable to nature. Cloud storage also supports some real time applications like Health Care, Intelligent transportation, Rescue Operation, Assembling of different parts in production of vehicles etc. Cloud Storage in some cases proves to be inadequate due to poor transfer rate and harmful due to security threats on cloud due to wireless networking access technique which could be easily challenged at any time resulting in a huge destruction.

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